

482/805 DWPI - (C) Derwent

AN - 1985-300422 [48]

XA - C1985-130085

XP - N1985-223609

TI - Mandrel alloy for drilling and expanding seamless steel pipe - comprises carbon, chromium, nickel, molybdenum and tungsten, cobalt, copper, titanium and/or zirconium, silicon and/or magnesium

DC - M27 P51 P52

PA - (SANY-) SANYO TOKUSHU SEIKO KK

- (HOKO-) SHIN HOKOKU SEITETSU KK

NP - 2

NC - 1

PN - JP60208458 A 19851021 DW1985-48 9p \*

AP: 1984JP-0064475 19840331

- JP89007147 B 19890207 DW1989-09

PR - 1984JP-0064475 19840331

AB - JP60208458 A

Mandrel alloy consists (by wt.) of C 0.14-0.18%, Cr 1-3%, Ni 1-9%, Mo and/or W 0.3-3% in total, Co 1-2%, Cu 1-2%, Ti and/or Zr 0.2-0.5% in total, Ni/Cr=1-3, and Si below 1.5% and/or Mn below 1.5% as deoxidising agent, and balance Fe and incidental impurities.

- ADVANTAGE - Increased durability. (0/6)

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⑮ 発明の名称 縫目なし鋼管の穿孔および拡張用芯合金

⑯ 特 願 昭59-64475

⑰ 出 願 昭59(1984)3月31日

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# 明 細 書

## 1. 発明の名称

縫目なし鋼管の穿孔および拡張用芯合金

## 2. 特許請求の範囲

1. 重量でCが0.1ないし0.25％、Crが1ないし3％、Niが1ないし9％、MoおよびWのいずれか1種または2種合計で0.3ないし3％、Coが1ないし2％、Cuが1ないし2％、TiおよびZrのいずれか1種もしくは2種合計が0.2ないし0.5％、残部Feおよび不可避的な微量不純物からなり、且つNi/Crの重量比の値が1から3である縫目なし鋼管穿孔および拡張用合金。

2. さらに必要に応じて脱酸剤としてSiが重量で1.5％以下、Mnが1.5％以下の何れかまたは両者を含有することを特徴とする特許請求の範囲第1項記載の芯合金。

## 3. 発明の詳細な説明

この発明は中央丸型鋼片から縫目なし鋼管を製造する際に用いられる穿孔および拡張用芯合金形成のための合金材料に関するものであって、

特願昭59-11899号(特開昭60-

号)発明になる合金をさらに改良したものである。

上記先出願明細書にも記載されているように、一般に縫目なし鋼管穿孔用の芯合金は、傾斜圧延ロールによって回転および前進する、およそ1200℃に加熱された中央丸形鋼片に縦方向に圧入されて、これによって鋼管の軸方向の穿孔が行われる。またこのようにして穿孔された鋼管は、同様に傾斜圧延ロールによって回転および前進する拡張用の別の芯合金が、およそ1000℃に加熱された鋼管の穿孔内に圧入されることによって、その拡張が行われる。

その結果、穿孔および拡張用の芯合金の表面に高温および高圧力が作用して、芯合金の表面には摩耗、芯合金材の塑性流動によるしわ、部分的な溶融損傷、あるいは管材との焼付きによるかじりや割れが発生し、これらによって起る芯合金の変形および損傷が進行して、比較的短使用回数うちに芯合金の寿命が盡きてその使用が不可能

となる。

穿孔用(または鉋管用)芯金の表面に生ずるこれらの損傷を防止するために、芯金を形成する合金に要求される特性は損傷の種類によって次のようになる。

(1) 収縮およびしわの発生防止のためには、合金の高温度における機械的強度が高いことが必要である。

(2) 割れ発生防止のためには、常温における合金の機械的強度と伸張性が高いことが必要である。

(3) 部分的な溶融損傷の発生防止のためには、芯金合金の組成のうち、地金への溶解度の小さい合金元素の添加をできるだけ少なくして、凝固割析や粒界析出によってこれらの合金元素が粒界に偏析して、部分的な融点低下および粒界脆化の生ずることを防止することが必要である。

(4) 焼付きによるかじりや割れの発生を防止するためには、スケール付け処理によって、芯金の表面に耐熱性と耐腐性を有する緻密なス

ケールが適度の厚さK形成されることが必要である。

既述の特開昭59-11899号発明の目的は、地金への溶解度が少なく、粒界偏析して部分的な溶融損傷の原因となるCと、スケール付け処理の際に形成されるスケール層を析出するCrとをできるだけ少なくし、Ni、MoおよびWの固溶体硬化により常温および高温度における機械的強度を高めることKによって、耐用度が従来のものよりも格段に優れた穿孔用芯金を得ることKにあった。

この目的は、重量でCが0.1ないし0.25%、Crが1ないし3%、Niが1ないし9%、MoおよびWのいずれか1種もしくは2種合計で0.3ないし3%、残部がFeおよび不可避免的な非金属物からなり、且つNi/Crの重量比の値が1ないし3の組成を有する合金を用いることKによって達成された。

本発明の目的は、上記特開昭59-11899号発明の合金をさらに改良して、穿孔用芯金の

耐用度をさらに向上させ得るような合金を得ることKにある。

この目的は、上記既発明における合金の成分組成のものK、さらに重量でCoを1ないし2%、Cuを1ないし2%、およびTiおよびZrのいずれか1種もしくは2種の合計を0.2ないし0.5%の割合で追加添加することKによって達成された。

なお、前記既出既発明の場合と同様に、上記の本発明における合金組成のものK、必要に応じて通常の脱酸剤として1.5%以下のSi、もしくは1.5%以下のMn、あるいはこの両者をさらに追加添加し得るものとする。

次に、本発明になる合金における各成分の組成範囲限定理由Kについて、特開昭59-11899号発明の要旨および図面における記述と一部重複させながら説明をする。

Cは、地金K固溶し、あるいは固溶限以上のCは熱処理によって様々な組織を示すことKによって、合金の常温および高温での機械的強度を向上させるので、合金の強度向上に最も有効な

元素である。しかしながら、Cがあまり多くなると、とくにCrと共存する場合Kは、Crの炭化物が粒界に析出して粒界脆化をひき起したり、またこの炭化物はMoやWを地金よりもよく固溶吸収するので、MoやWの添加による地金の固溶強化効果を減ずるなどの逆効果をも併せて持つものである。

本発明になる芯金用合金は、芯金の部分的な溶融損傷を防止する見地から、従来のこの種合金と異なり、常温および高温度における機械的強度を主として固溶体硬化によることKしているので、Cの含有量はできるだけ低い方が望ましい。しかしながらあまりCの含有量が低いと、必要とする機械的強度を保持させるためにNi含有量を高める必要を生じ、これでは経済的にコスト高となる。またC含有量があまりにも低いと溶湯の流動性が減少し、従ってその鋳造性が悪化する。

本発明になる芯金用合金においては、C含有量の下限値は、上記の経済性と鋳造性との観点

からこれを0.1多とし、上限値は穿孔用芯金の部分的腐蝕防止の観点からこれを0.25多とした。

Siは、一般の脱酸剤として、合金の脱酸調整用に必要に応じて合金に添加されるが、Siが多過ぎると合金の韌性が低下するとともに、穿孔用芯金の表面に断熱性と潤滑性を有する緻密なスケールを付着させるために施される一般のスケール付け処理時に、スケール中にファイヤライト( $\text{FeO} \cdot \text{SiO}_2$ )を生成してスケールを脆弱にする。

よってSi含有量の上限値を1.5多に定めた。下限については別に制限はない。

Mnも一般の脱酸剤として、合金の脱酸調整用に必要に応じて合金に添加される。そしてMnが多過ぎるとSiの場合と同様にスケールを脆弱にする。

よってMn含有量の上限値を1.5多と定めた。下限については別に制限はない。

CrおよびNiの成分範囲限定理由については、

両成分の比率が重要であるので、両者をまとめて説明をする。

Crは地金に固溶し、あるいはCと結合して炭化物を形成して、常温あるいは高温域における機械的強度を高めるとともに、合金の耐酸化性を向上させるのに有効な元素である。然しながらCr含有量が高すぎると、耐酸化性が向上することによって芯金の表面に断熱性と潤滑性を有するスケールを付着させる一般のスケール付け処理を施す際に、生成するスケール層の厚さが増くなり、既述の芯金に生ずる損傷のうち、管材との脱付きによるかじりが多発する。またCr含有量が低すぎると、常温および高温域における合金の機械的強度が低下し、芯金に強度不足による摩耗、しわ、あるいは割れが発生する。

NiはCと炭化物を形成することなく地金に全部固溶して、固溶体硬化によって常温および高温域における機械的強度を高めるのに有効な元素である。然しながら、NiはCrに比べて高価であるので、Niだけで常温および高温域における

合金の機械的強度を高めるとコスト高となり、またCrと共存する場合ほどには高い機械的強度は得られない。また、Niの添加は、Cr添加の場合に比べて、スケール付け処理による付着スケール層が薄くなる弊害ははるかに少ない。

従って、芯金合金に十分な常温および高温域における機械的強度、および適度な厚さのスケール層を与え、さらに合金に経済性を持たせるために、スケール層を薄くすることなく機械的強度を高めることのできるNiを主体とし、これに許容し得る範囲のCrを添加して、常温および高温域における機械的強度を補完するとともに、Niの添加量を削減することにした。

上記の見地から、スケール層の厚さを薄くしないためにCr含有量の上限を3多とし、下限は機械的強度を補完するためにこれを1多とした。またNiは機械的強度を高めるために、その含量をCr含有量の1倍から3倍、すなわちNi/Crの重量比の値を1ないし3と定めた。

Ni/Cr比の値を1ないし3と定めた根拠を第

1図および第2図の1組の曲線図、ならびに第3図および第4図の1組の曲線図を用いて説明する。第1図はCr含有量が1.4多の場合の常温における合金の機械的強度に及ぼすNi/Cr比の影響を示す曲線図、第2図は同温度900℃における同様の影響曲線図、第3図はCr含有量が2.8多の場合の常温における同様の影響曲線図、第4図は同温度900℃における同様の影響曲線図である。

これらの曲線図から判るように、穿孔用芯金の耐用度の低下をもたらす損傷の一つである割れを防止するのに必要な常温の引張強さと伸び率は、Ni/Cr比が1以下では引張強さが45ないし5.0  $\text{kg}/\text{mm}^2$  であって強度不足であり、Ni/Cr比が3以上では伸び率が著しく低下して割れの防止には不適当である。また損傷の他の一つである芯金表面の摩耗およびしわを防止するために必要な高温域における引張強さは、Ni/Cr比が3以上では5.2ないし5.3  $\text{kg}/\text{mm}^2$  となっていて強度不足であるとともに、伸び率が著しく低

下するのが利る。

以上の結果から判断して、本発明になる芯合金中のNi/Cr比の値を1ないし3の範囲で選ぶことに定めた。

MoおよびWは合金地金に固溶し、あるいはCと結合して炭化物を形成して、とくに合金の高温度における機械的強度を高めるのに有効な元素である。反面、MoおよびW含有量の増加はスケール付け処理により芯合金表面に生成付着するスケール層を脆化する。本発明になる芯合金の高温機械的性質に及ぼすMoおよびW添加の影響の例が図5図に示されている。この曲線図はCr含有量が28%、Ni/Cr比が2.0の場合、試験温度が900℃の場合Mo、W、またはMoとWの合計量の变化が、合金の引張り強さおよび伸び率に及ぼす影響を示すものである。

この曲線図によると、MoおよびWの何れか1種もしくは2種合計の添加量が0.2%までは高温引張り強さの向上に効果がない。しかしながら、この添加量が0.3%から1.5%までは添加

量の増加とともに引張り強さは緩やかに増加し、添加量が1.5%から2.0%までは引張り強さは添加量の増加とともに急激に増加する。そして2.0%以上の添加では引張り強さは再び緩やかな増加に転ずるのを見ることが出来る。

本発明合金によって製作された芯金によって1200℃近傍に加熱された中興丸形鋼片を穿孔する場合に、穿孔される鋼片の材質が単なる炭素鋼であるならば、MoおよびWのいずれか1種もしくは2種合計の添加量が1.5%以下の本発明合金による穿孔用芯金で十分に従来の芯金の耐用度を上回ることが出来る。しかしながら、穿孔される鋼片の材質が13%クロム鋼もしくは24%クロム鋼のような特殊鋼である場合には、MoおよびWの何れか1種もしくは2種合計の添加量は1.5%から3.0%までであることが必要である。

従って、本発明になる合金におけるMoおよびWのいずれか1種もしくは2種合計の添加量は、これを0.3ないし3%と定めた。

C<sub>0</sub>は一般の炭素鋼、もしくは本発明になる芯合金のような低合金鋼に添加される元素のうち、鋼の焼入性を低下させる唯一の元素である。

穿孔用芯金は、1200℃近傍に加熱された中興丸形鋼片中に圧入されるので、穿孔直後の穿孔用芯金の表面温度は1200℃から1300℃近傍に、表面から約5mm内部では800℃近傍に、そしてさらに内部では700℃以下の温度となる。

このような状態に加熱された芯金は、穿孔直後に冷水によって常温にまで冷却されたのち、再び新たな鋼片中に圧入され、こうして加熱および冷却が繰返される。この繰返しによって芯金の表面に細かい亀甲状の割れが生じて、これが被穿孔パイプの内面に圧縮応力発生させるものである。この亀甲状の割れは主として加熱冷却の繰返しによって生ずる熱応力に起因する。

一般に焼入性が低く、焼入変態のない場合の鋼体の熱応力は、鋼体の表面では圧縮応力が、鋼体の中心部では引張応力が発生する。これに

対して、焼入性が高く、焼入変態が生ずる場合の鋼体の熱応力は、その表面では引張応力が、その中心部では圧縮応力が発生する。すなわち両者の場合に熱応力の分布が逆転するのである。そして、一般に表面が圧縮応力となる焼入変態のない加熱冷却の繰返しの方が亀甲割れの発生が少ない。

焼入性の大小は、丸棒鋼片を水焼入れしたのち、その断面硬度を測定し、硬度がロックウェルCスケール40以上になる硬化層の厚さ $\delta$ と丸棒の半径 $r$ との比率 $\delta/r$ を以てこれを表わすことができる。すなわち $\delta/r$ 値が小さくなる程焼入性が低下することを表わす。

本発明合金による半径25mmの丸棒を水焼入れした場合の $\delta/r$ 値に及ぼすC<sub>0</sub>成分含有量の影響の一例が図6図の曲線図に示されている。この曲線図から、C<sub>0</sub>が1.75%までは焼入性の低下が顕著であるが、C<sub>0</sub>が1.75%を超えるとその効果が少ないことが判る。

よって本発明合金のC<sub>0</sub>添加量の下限は、焼入

性低下の効果の見地から1多とし、上限は、経済的コスト高となる際には焼入性低下の効果があり得られない見地からこれを2多とした。

Cuは地金中に微細に析出して、常温の引張強さを高めるのに有効な元素である。また既述した耐熱性と潤滑性とを有するスケール付けの処理の際に、スケール直下の地金中に富化されて、スケールの地金への密着性を改善するのに有効な元素である。しかしながら、添加量が1多以下では常温の引張強さの向上は少なく、添加量が多過ぎると、スケール直下に富化されたCuが高温度で地金の結晶粒界に浸潤して、芯金の表面部を脆化する。

よって本発明合金におけるCuの添加量下限を1多とし、上限を2多とした。

TiおよびZrはCrよりも優先してCと結合して炭化物を形成する。そしてTiおよびZrの炭化物はCrの炭化物とはちがって、地金中に均一に分散すること、および高温度における地金中への溶解度がCrの炭化物に比べて極めて小さい

ことから、粒界の部分的な融点低下および粒界の脆化を軽減するとともに、高温度における引張強さを高めるのに有効な元素である。さらに、Crよりも優先して炭化物を形成するのでCrの炭化物量が減少する結果、Cr炭化物中に吸収されるCr、WおよびMoが減少し、従ってこれらの元素の地金中の濃度が高くなって、固溶体硬化によって合金の高温度における引張強さが向上する。しかしながら、TiおよびZrの添加量が多過ぎると、合金を大気中で溶解する場合に、著しく溶解の流動性が減せられ、芯金製作の際に鍛造性を害することになる。

よって本発明合金におけるTiおよびZrの1種あるいは2種合計の添加量の上限を0.5多、下限を0.2多と定めた。

以上、継目なし鋼管の穿孔用芯金合金について述べたが、同材質用芯金合金についても全く穿孔用芯金合金と同様であるからその説明を省略する。

次に実施例について説明をする。

本発明になる穿孔用芯金合金の実施諸例の組成を第1表に示す。第1表には先発明である特開2006-11899号発明になる合金、および従来公知のこの種合金の組成をも併記してある。

第1表に示された組成の各合金を素材として、JIS-Z-2201の規定による10号常温引張試験片、JIS-G-0567号の規定による高温度引張試験片、および直径が6.9 mm、7.2 mm、および7.5 mmのアッセルミル用穿孔芯金をそれぞれ製作した。高温度引張り試験は温度900℃で毎分5多の速度度でおこなわれた。これらの芯金を用いて、実際にJISの8UJ 2種(C約1多、Cr約1.5)のベアリング鋼材(いわゆる高炭素クロム軸受け鋼材)をアッセルミルを用いて穿孔試験を行った。これらの諸試験の結果が第2表に示されている。芯金の耐用度は穿孔用芯金1個当たりの平均穿孔本数で表わされている。

第2表に見られるように、本発明になる合金の常温および高温度における機械的強度は、従

来公知のこの種合金の1.5倍ないし3倍、特開2006-11899号発明合金のそれらとはほぼ同等もしくは幾らか大きいことが判る。そして、本発明合金で製作された芯金の耐用度は、公知の合金のものの2ないし5倍、特開2006-11899号発明合金のものの1.5ないし2倍となっているのを見る。この本発明合金による芯金の耐用度が増大しているのは、合金のCu添加による芯金表面の亀甲割れの減少、Cu添加によるスケールの密着、TiおよびZrの添加による炭化物の粒界腐食防止の諸効果によるものである。

第1表 合金の組成表 (重量%)

|                          |                  | C    | Si   | Mn   | Cr   | Ni   | Mo   | W    | P     | S     | Co   | Cu   | Ti   | Zr   | Nb   | Fe |
|--------------------------|------------------|------|------|------|------|------|------|------|-------|-------|------|------|------|------|------|----|
|                          |                  |      |      |      |      |      |      |      |       |       |      |      |      |      |      |    |
| 実施例合金                    | 1                | 0.18 | 0.68 | 0.62 | 1.58 | 3.06 | 0.42 | -    | 0.026 | 0.018 | 1.02 | 1.14 | 0.24 | -    | 1.94 | 残部 |
|                          | 2                | 0.18 | 0.62 | 0.64 | 1.58 | 3.10 | 0.48 | -    | 0.027 | 0.020 | 1.18 | 1.10 | 0.26 | 0.22 | 1.96 | 〃  |
|                          | 3                | 0.16 | 0.71 | 0.71 | 1.52 | 3.10 | 0.44 | -    | 0.024 | 0.018 | 1.12 | 1.84 | -    | 0.28 | 2.04 | 〃  |
|                          | 4                | 0.17 | 0.64 | 0.68 | 1.54 | 3.08 | 0.43 | -    | 0.024 | 0.022 | 1.08 | 1.87 | 0.18 | 0.26 | 2.00 | 〃  |
|                          | 5                | 0.17 | 0.62 | 0.59 | 2.54 | 5.98 | 0.50 | 0.73 | 0.026 | 0.016 | 1.56 | 1.06 | 0.32 | -    | 2.35 | 〃  |
|                          | 6                | 0.15 | 0.62 | 0.57 | 2.49 | 5.96 | 0.48 | 0.76 | 0.024 | 0.016 | 1.68 | 1.06 | -    | 0.29 | 2.39 | 〃  |
|                          | 7                | 0.18 | 0.66 | 0.60 | 2.52 | 5.95 | 0.46 | 0.76 | 0.026 | 0.020 | 1.70 | 1.54 | 0.26 | 0.18 | 2.36 | 〃  |
|                          | 8                | 0.16 | 0.58 | 0.56 | 2.52 | 5.96 | 0.48 | 0.74 | 0.025 | 0.018 | 1.48 | 1.46 | 0.17 | 0.18 | 2.37 | 〃  |
|                          | 9                | 0.24 | 0.69 | 0.72 | 2.51 | 5.94 | 0.52 | 0.75 | 0.026 | 0.019 | 1.52 | 1.94 | 0.23 | 0.20 | 2.37 | 〃  |
| 特開昭五九・一一八九九号発明合金<br>公知合金 | 1                | 0.17 | 0.62 | 0.68 | 1.34 | 3.90 | 0.42 | -    | 0.030 | 0.024 | -    | -    | -    | -    | 2.91 | 〃  |
|                          | 2                | 0.17 | 0.58 | 0.62 | 2.56 | 6.23 | 0.48 | -    | 0.028 | 0.018 | -    | -    | -    | -    | 2.43 | 〃  |
|                          | 3                | 0.14 | 0.60 | 0.54 | 2.85 | 5.83 | 0.42 | -    | 0.028 | 0.018 | -    | -    | -    | -    | 2.04 | 〃  |
|                          | 4                | 0.16 | 0.60 | 0.52 | 2.62 | 3.87 | 0.40 | -    | 0.026 | 0.020 | -    | -    | -    | -    | 1.48 | 〃  |
|                          | 5                | 0.17 | 0.68 | 0.54 | 1.39 | 1.46 | 0.43 | -    | 0.026 | 0.018 | -    | -    | -    | -    | 1.05 | 〃  |
|                          | 6                | 0.18 | 0.70 | 0.68 | 2.68 | 6.21 | 0.40 | 0.32 | 0.024 | 0.016 | -    | -    | -    | -    | 2.32 | 〃  |
|                          | 7                | 0.15 | 0.57 | 0.62 | 1.76 | 2.84 | 0.50 | 0.73 | 0.026 | 0.020 | -    | -    | -    | -    | 1.62 | 〃  |
|                          | 8                | 0.15 | 0.56 | 0.64 | 1.55 | 2.75 | 0.47 | 1.62 | 0.028 | 0.022 | -    | -    | -    | -    | 1.77 | 〃  |
|                          | 9                | 0.25 | 0.64 | 0.66 | 1.55 | 2.68 | 0.60 | 2.02 | 0.024 | 0.016 | -    | -    | -    | -    | 1.73 | 〃  |
|                          | 3Cr-1Ni<br>鋼     | 0.32 | 0.74 | 0.62 | 3.05 | 1.02 | -    | -    | 0.026 | 0.020 | -    | -    | -    | -    | 0.33 | 〃  |
|                          | 15Cr-0.75Ni<br>鋼 | 0.23 | 0.61 | 0.68 | 1.64 | 0.68 | 0.12 | -    | 0.028 | 0.016 | 1.26 | 1.08 | -    | -    | 0.41 | 〃  |

第2表 諸特性

|                          |                  | 常温の機械的性質                      |            | 900°の機械的性質                    |            | 穿孔管材<br>の材質 | 耐用度<br>(穿孔本数/1個) |
|--------------------------|------------------|-------------------------------|------------|-------------------------------|------------|-------------|------------------|
|                          |                  | 引張強さ<br>(kg/mm <sup>2</sup> ) | 伸び率<br>(%) | 引張強さ<br>(kg/mm <sup>2</sup> ) | 伸び率<br>(%) |             |                  |
| 実施例合金                    | 1                | 125.6                         | 5.6        | 7.8                           | 12.4       | ヘアライン鋼      | 20~70            |
|                          | 2                | 125.0                         | 5.8        | 7.8                           | 10.8       | 〃           | 20~70            |
|                          | 3                | 126.0                         | 5.6        | 7.4                           | 14.6       | 〃           | 20~70            |
|                          | 4                | 126.8                         | 5.4        | 7.6                           | 11.8       | 〃           | 20~70            |
|                          | 5                | 128.4                         | 4.8        | 8.2                           | 8.6        | 〃           | 50~120           |
|                          | 6                | 127.8                         | 4.6        | 8.2                           | 8.4        | 〃           | 50~120           |
|                          | 7                | 128.6                         | 4.6        | 8.6                           | 7.8        | 〃           | 50~120           |
|                          | 8                | 129.0                         | 4.2        | 8.7                           | 7.2        | 〃           | 50~120           |
|                          | 9                | 128.0                         | 4.2        | 8.4                           | 7.6        | 〃           | 50~120           |
| 特開昭五九・一一八九九号発明合金<br>公知合金 | 1                | 101.0                         | 20.0       | 7.9                           | 31.2       | 〃           | 20~50            |
|                          | 2                | 125.2                         | 5.4        | 7.3                           | 12.0       | 〃           | 20~50            |
|                          | 3                | 121.6                         | 7.0        | 7.8                           | 9.2        | 〃           | 20~50            |
|                          | 4                | 124.2                         | 7.2        | 7.2                           | 11.4       | 〃           | 20~50            |
|                          | 5                | 60.2                          | 29.5       | 7.0                           | 58.0       | 〃           | 20~50            |
|                          | 6                | 136.9                         | 4.8        | 8.0                           | 8.5        | 〃           | 30~50            |
|                          | 7                | 117.0                         | 10.2       | 8.5                           | 7.5        | 〃           | 30~60            |
|                          | 8                | 110.8                         | 10.9       | 15.0                          | 7.0        | 〃           | 30~60            |
|                          | 9                | 123.0                         | 6.8        | 16.0                          | 6.0        | 〃           | 30~60            |
|                          | 3Cr-1Ni<br>鋼     | 63.0                          | 16.0       | 5.2                           | 48.2       | 〃           | 10~30            |
|                          | 15Cr-0.75Ni<br>鋼 | 61.8                          | 21.6       | 5.8                           | 52.6       | 〃           | 13~35            |

## 4. 図面の簡単な説明

第1図は本発明合金のCr含有量が1.4%の場合の常温機械的性質に及ぼすNi/Cr重量比の影響を示す曲線図。

第2図は本発明合金のCr含有量が1.4%の場合の温度900℃における機械的性質に及ぼすNi/Cr重量比の影響を示す曲線図。

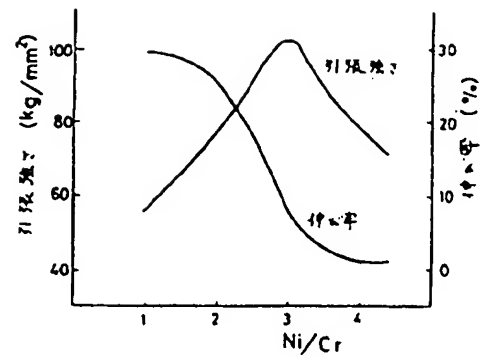
第3図は本発明合金のCr含有量が2.8%の場合の常温機械的性質に及ぼすNi/Cr重量比の影響を示す曲線図。

第4図は本発明合金のCr含有量が2.8%の場合の温度900℃における機械的性質に及ぼすNi/Cr重量比の影響を示す曲線図。

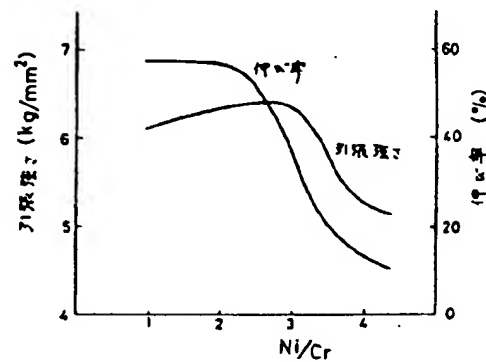
第5図は本発明合金のCr含有量が2.8%でNi/Cr重量比が2.0の場合の温度900℃における機械的性質に及ぼすMoおよびW添加の影響を示す曲線図。

第6図は本発明合金の鍛造性に及ぼすCo添加の影響を示す曲線図である。

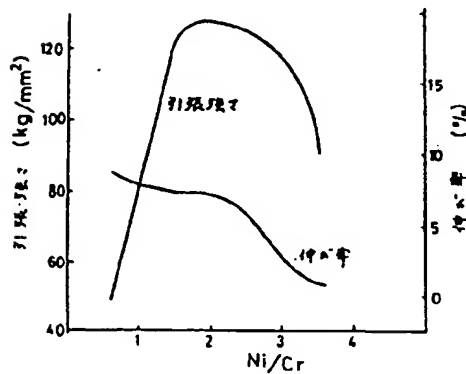
第1図



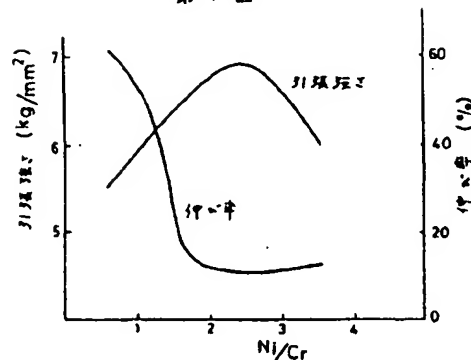
第2図



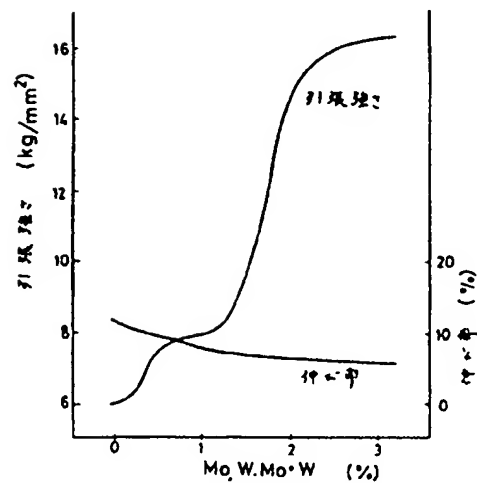
第3図



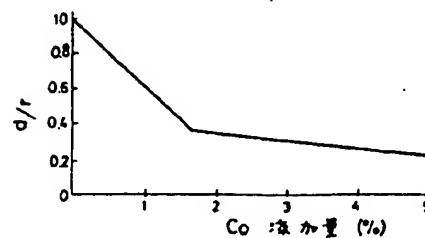
第4図



第5図



第6図





## 手 続 補 正 書

特許第60-208458(B)

特許庁長官 志 賀 孝 殿

## 1. 事件の表示

特許第59-64475号

## 2. 発明の名称

難溶なれ鋼管の穿孔および並用合金

## 3. 補正をする者

事件との関係 特許出願人

新機園製鉄株式会社

(ほか1名)

## 4. 代理人

(住所) 東京都港区西門1丁目5番5号 第17番ビル  
〒105 電話 四(502) 3181 (大代表)

氏名 (547) 代理人 鈴 江 武 彦 印 蔵 上

## 5. 自発補正

## 6. 補正の対象

明 細 書

## 7. 補正の内容

(1) 特許請求の範囲、明細書全文を別紙の通り訂正する。

## (2) 明細書中、下記の訂正を行います。

イ. 4頁下から9行、「Cが0.1ないし0.25%、」を「Cが0.14ないし0.18%、」と訂正。

ロ. 6頁最下行、「鋼点」を「実験的見地」と訂正。

ハ. 7頁1行、「0.1%」を「0.14%」と訂正。

ニ. 同頁2行、「鋼点」を「実験的見地」と訂正。同行「0.25%」を「0.18%」と訂正。

ホ. 同頁3行、「た。」の次に「(後掲実施例参照)」を挿入。

ヘ. 19頁および20頁のそれぞれ第1表および第2表を別紙のとおり訂正。

第 1 表 合金の組成表 (重量%)

|       |               | C    | Si   | Mn   | Cr   | Ni   | Mo   | W    | P     | S     | Co   | Cu   | Ti   | Zr   | Nb/Cr | Pe |
|-------|---------------|------|------|------|------|------|------|------|-------|-------|------|------|------|------|-------|----|
| 実施例合金 | 1             | 0.18 | 0.68 | 0.62 | 1.58 | 3.06 | 0.42 | -    | 0.026 | 0.018 | 1.02 | 1.14 | 0.24 | -    | 1.94  | 検部 |
|       | 2             | 0.18 | 0.62 | 0.64 | 1.58 | 3.10 | 0.48 | -    | 0.027 | 0.020 | 1.18 | 1.10 | 0.26 | 0.22 | 1.96  | -  |
|       | 3             | 0.16 | 0.71 | 0.71 | 1.62 | 3.10 | 0.44 | -    | 0.024 | 0.018 | 1.12 | 1.84 | -    | 0.28 | 2.04  | -  |
|       | 4             | 0.17 | 0.64 | 0.68 | 1.54 | 3.08 | 0.43 | -    | 0.024 | 0.022 | 1.08 | 1.87 | 0.18 | 0.26 | 2.00  | -  |
|       | 5             | 0.17 | 0.62 | 0.59 | 2.54 | 5.98 | 0.50 | 0.73 | 0.026 | 0.016 | 1.56 | 1.06 | 0.32 | -    | 2.35  | -  |
|       | 6             | 0.16 | 0.62 | 0.57 | 2.49 | 5.96 | 0.48 | 0.76 | 0.024 | 0.016 | 1.68 | 1.06 | -    | 0.29 | 2.39  | -  |
|       | 7             | 0.18 | 0.66 | 0.60 | 2.52 | 5.55 | 0.46 | 0.76 | 0.026 | 0.020 | 1.70 | 1.54 | 0.26 | 0.18 | 2.36  | -  |
|       | 8             | 0.16 | 0.58 | 0.56 | 2.62 | 5.96 | 0.48 | 0.74 | 0.025 | 0.018 | 1.48 | 1.46 | 0.17 | 0.18 | 2.37  | -  |
| 比較例合金 | 1             | 0.17 | 0.62 | 0.68 | 1.34 | 3.90 | 0.42 | -    | 0.030 | 0.024 | -    | -    | -    | -    | 2.91  | -  |
|       | 2             | 0.17 | 0.58 | 0.62 | 2.56 | 6.23 | 0.48 | -    | 0.028 | 0.018 | -    | -    | -    | -    | 2.43  | -  |
|       | 3             | 0.14 | 0.60 | 0.54 | 2.85 | 5.83 | 0.42 | -    | 0.028 | 0.018 | -    | -    | -    | -    | 2.04  | -  |
|       | 4             | 0.16 | 0.60 | 0.52 | 2.62 | 3.87 | 0.40 | -    | 0.026 | 0.020 | -    | -    | -    | -    | 1.48  | -  |
|       | 5             | 0.17 | 0.68 | 0.54 | 1.39 | 1.46 | 0.43 | -    | 0.026 | 0.018 | -    | -    | -    | -    | 1.05  | -  |
|       | 6             | 0.18 | 0.70 | 0.68 | 2.68 | 6.21 | 0.40 | 0.32 | 0.024 | 0.016 | -    | -    | -    | -    | 2.32  | -  |
|       | 7             | 0.16 | 0.57 | 0.62 | 1.75 | 2.64 | 0.50 | 0.73 | 0.026 | 0.020 | -    | -    | -    | -    | 1.62  | -  |
|       | 8             | 0.16 | 0.56 | 0.64 | 1.55 | 2.76 | 0.47 | 1.62 | 0.028 | 0.022 | -    | -    | -    | -    | 1.77  | -  |
| 公知合金  | 3Cr-1Ni鋼      | 0.32 | 0.74 | 0.62 | 3.05 | 1.02 | -    | -    | 0.026 | 0.020 | -    | -    | -    | -    | 0.33  | -  |
|       | 1.5Cr-0.75Ni鋼 | 0.23 | 0.61 | 0.68 | 1.64 | 0.68 | 0.12 | -    | 0.028 | 0.016 | 1.26 | 1.08 | -    | -    | 0.41  | -  |

表 2 発 明 特 性

|  |                     | 常温の機械的性質                      |            | 900°の機械的性質                    |            | 穿孔管材<br>の材質 | 耐 用 度<br>(穿孔本数/1組) |
|--|---------------------|-------------------------------|------------|-------------------------------|------------|-------------|--------------------|
|  |                     | 引張強さ<br>(Kg/mm <sup>2</sup> ) | 伸び率<br>(%) | 引張強さ<br>(Kg/mm <sup>2</sup> ) | 伸び率<br>(%) |             |                    |
| 実<br>例<br>合<br>金   | 例 1                 | 125.6                         | 5.8        | 7.8                           | 12.4       | ペアリング鋼      | 20~70              |
|  | 例 2                 | 125.0                         | 5.8        | 7.8                           | 10.8       | "           | 20~70              |
|  | 例 3                 | 126.0                         | 5.6        | 7.4                           | 14.6       | "           | 20~70              |
|  | 例 4                 | 126.8                         | 5.4        | 7.6                           | 11.8       | "           | 20~70              |
|  | 例 5                 | 128.4                         | 4.8        | 8.2                           | 8.6        | "           | 50~120             |
|  | 例 6                 | 127.8                         | 4.6        | 8.2                           | 8.4        | "           | 50~120             |
|  | 例 7                 | 128.6                         | 4.6        | 8.6                           | 7.8        | "           | 50~120             |
|  | 例 8                 | 129.0                         | 4.2        | 8.7                           | 7.2        | "           | 50~120             |
| 特<br>許<br>五<br>九<br>一<br>一<br>八<br>九<br>七<br>号<br>特<br>許<br>合<br>金 | 例 1                 | 101.0                         | 20.0       | 7.9                           | 31.2       | "           | 20~50              |
|  | 例 2                 | 125.2                         | 5.4        | 7.3                           | 12.0       | "           | 20~50              |
|  | 例 3                 | 121.6                         | 7.0        | 7.8                           | 9.2        | "           | 20~50              |
|  | 例 4                 | 124.2                         | 7.2        | 7.2                           | 11.4       | "           | 20~50              |
|  | 例 5                 | 60.2                          | 29.5       | 7.0                           | 58.0       | "           | 20~50              |
|  | 例 6                 | 136.9                         | 4.8        | 8.0                           | 8.5        | "           | 30~50              |
|  | 例 7                 | 117.0                         | 10.2       | 8.5                           | 7.5        | "           | 30~60              |
|  | 例 8                 | 110.4                         | 10.9       | 15.0                          | 7.0        | "           | 30~60              |
| 公<br>知<br>合<br>金   | 3Cr-1Ni<br>鋼 鋼      | 63.0                          | 16.0       | 5.2                           | 48.2       | "           | 10~30              |
|  | 1.5Cr-0.75Ni<br>鋼 鋼 | 61.8                          | 21.6       | 5.8                           | 52.6       | "           | 13~35              |

## 2. 特許請求の範囲

1. 重量でCが0.14ないし0.18%、Crが1ないし3%、Niが1ないし9%、MoおよびWのいずれか1種または2種合計で0.3ないし3%、Coが1ないし2%、Cuが1ないし2%、TiおよびZrのいずれか1種もしくは2種合計が0.2ないし0.5%、残部Feおよび不可避免的な微細不純物からなり、且つNi/Crの重量比の値が1から3である難目なし鋼管の穿孔および拡張用合金。

2. さらに必要に応じて脱酸剤としてSiが重量で1.5%以下、Mnが1.5%以下の何れかまたは両者を含有することを特徴とする特許請求の範囲第1項記載の合金。

(19) Japan Patent Office (JP)  
(11) Japanese Unexamined Patent Application Publication S60-208458  
(12) Japanese Unexamined Patent Application Publication (A)

|                                    | Classification | Internal Office  |
|------------------------------------|----------------|--|
| (51) Int Cl. <sup>4</sup> :        | Symbols:       | Registration Nos.: (43) Disclosure Date: 21 October 1985 |
| C22C 38/52                         |                | 7147-4K  |
| B21B 25/00                         |                | 7819-4E  |
| B21C 3/02                          |                | 6778-4E  |
| C22C 38/52                         |                | 7217-4K  |
| Request for Examination: Submitted |                | Number of Claims/Inventions: 1 (Total of 9 pages)        |

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(54) Title of the Invention: Core Metal Alloy for Piercing or Expanding Seamless Steel Pipe  
(21) Japanese Patent Application S59-64475  
(22) Filing Date: 31 March 1984

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SPECIFICATIONS

1. Title of the Invention

Core Metal Alloy for Piercing or Expanding Seamless Steel Pipe

2. Scope of Patent Claims

1. A core metal alloy for piercing or expanding [insertion] a [end insertion] seamless steel pipe made from, by weight, 0.1 to 0.25% C, 1 to 3% Cr, 1 to 9% Ni, 0.3 to 3% of a total of one or two types of Mo and W, 1 to 2% of Co, 1 to 2% of Cu, 0.2 to 0.5% of a total of one or two types of Ti and Zr, and the balance Fe with inevitable trace quantities of impurities, and a weight ratio value for Ni/Cr of between 1 and 3.

2. A core metal alloy recited in Claim 1 characterized by the fact of further containing, by weight, according to need 1.5% or less of Si and/or 1.5% or less of Mn and as a deoxidizer.

3. Detailed Description of the Invention

The present invention relates to an alloy material for forming a core metal for piercing or expansion when manufacturing seamless steel pipes from solid round billets, and further improves the alloy in the Patent Application S59-11899 [i.e., 1984-11899] (Unexamined Patent Application Gazette Number S60 [i.e., 1985]) invention.

As recited in the Specification of the aforementioned antedated application, generally, a core metal for piercing a seamless metal pipe is pressed lengthwise by a solid round steel billet heated to approximately 1200°C that advances and rotates due to an oblique rolling roll, and piercing is thereby made in the axial direction of the steel pipe. A pierced steel pipe pierced in this manner can be expanded

by a separate core metal for expansion that advances and rotates similarly due to an oblique rolling roll being pressed in the pierce hole of the steel pipe heated to approximately 1000°C.

As a result, high temperature and a high stress act on the surface of the core metal for piercing or expansion, abrasion on the surface of the core metal, wrinkling due to plastic flow of the core metal material, partial melting damage, or galling or cracks due to seizures with the pipe material occur, deformation or damage to the core metal occurring thereby proceed, the life with the number of uses of the core metal is comparatively shortened, and the use becomes impossible.

The properties demanded of an alloy to form a core metal in order to prevent such damage that occurs on the surface of core metal for piercing (or expansion) differ as follows according to the type of damage.

(1) In order to prevent the occurrence of abrasion or wrinkling, the mechanical strength of the alloy needs to be high at high temperatures.

(2) In order to prevent the occurrence of cracks, the mechanical strength and extensibility of the alloy need to be high at ordinary temperatures.

(3) In order to prevent the occurrence of partial melting damage, it is necessary to prevent partial lowering of the melting point and grain boundary embrittlement from occurring by adding as few alloy elements with a low melting point to the bare metal as possible in the composition of the core metal alloy, and segregating these alloy elements by grain boundary using solidification segregation and grain boundary separation.

(4) In order to prevent the occurrence of galling and cracks due to seizures, a fine scale needs to be formed with an appropriate thickness having thermal insulation and lubrication on the surface of the core metal due to scale attachment.

The object of the Patent Application Number S59-11899 [i.e., 1984-11899] invention described above was to obtain a core metal for piercing markedly superior in duration compared to conventional core metals by increasing the mechanical strength and ordinary and high temperatures using solid solution hardening of Ni, Mo and W, grain boundary segregating and decreasing as much as possible the quantity of C which is a cause of partial solution damage and the quantity of Cr which thins the scale layer formed during scale attachment, and decreasing the solubility in the bare metal.

This object was achieved using an alloy having, by weight, {A}<sup>1</sup> 0.1 to 0.25% C, 1 to 3% Cr, 1 to 9% Ni, 0.3 to 3% of a total of one or two types of Mo and W, and the balance Fe with inevitable trace quantities of impurities, and a composition with a weight ratio value for Ni/Cr of between 1 and 3.

The object of the present invention is to further improve the alloy in the aforementioned Patent Application Number S59-11899 [i.e., 1984-11899] invention, and obtain an alloy for piercing whose durability is further improved.

This object was achieved by adding to the component composition of the alloy of the aforementioned invention additives in a ratio of, by weight, 1 to 2% Co, 1 to 2% Cu, and 0.2 to 0.5% of a total of one or two types of Ti and Zr.

Similar to the aforementioned antedated application invention, the additives of either 1.5% or less of Si and 1.5% or less of Mn or both may be added as ordinary deoxidizers according to need to the alloy composition of the present invention mentioned above.

Next is a description, which duplicates some of the above description, of the Specification and Drawings of Patent Application Number S59-11899 [i.e., 1984-11899] for the range limitations of the composition of each component in an alloy of the present invention.

C is an effective element for improving the strength of an alloy because it increases the mechanical strength of alloys at ordinary and high temperatures by exhibiting various aspects when C is melted in bare metal or undergoes heat treatment above the solution point. However, if there is too much C, and particularly when co-existing with Cr, the Cr carbide separates at the grain boundary, causing

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<sup>1</sup> [Translator's note: Braces indicate sections subject to the amendment following the patent added by the translator for ease of reference.]

grain boundary embrittlement, and the carbide dissolves and absorbs more Mo and W than the bare metal, so the reverse effects such as solution strengthening effects of the bare metal due to adding Mo and W are caused.

An alloy for a core metal according to the present invention differs from this sort of conventional alloys from a perspective of preventing partial melting damage to the core metal, and solid solution hardening is mainly used for mechanical strength at ordinary and high temperatures, so it is desirable to have as little contained C as possible. Nevertheless, when the quantity of contained C is too little, a need arises to increase the quantity of the contained Ni to maintain the required mechanical strength, and this is economically costly. Also, if the quantity of contained C is too little, the liquid fluidity decreases, and the castability thereby worsens.

For an alloy for core metal according to the present invention, the lower limit value of the quantity of contained C was set to {C} 0.1% from the aforementioned {B} perspective of economy and castability, and the upper limit value was set to {D} 0.25% from the {D} perspective of preventing partial melting damage to the core metal for piercing. {E}

Si is added as a general deoxidizer to alloys according to need to adjust the deoxidation of the alloy, but if there is too much Si, the toughness of the alloy decreases, and fayalite ( $\text{FeO} \cdot \text{SiO}_2$ ) is generated in the scale, embrittling it during general scale attachment performed to cause a fine scale having heat insulation and lubrication to attach to the surface of the core metal for piercing.

Thus, the upper limit value for the quantity of contained Si was fixed at 1.5%. There is no particular limitation on the lower limit.

Mn is also added to alloys as a general deoxidizer according to need to adjust the deoxidation of the alloy. When there is too much Mn, the scale is embrittled as with the case of Si.

Thus, the upper limit value for the quantity of contained Mn was fixed at 1.5%. There is no particular limitation on the lower limit.

The comparative rhythm [sic]<sup>2</sup> of Cr and Ni is important, so the reason for the range limitation of the Cr and Ni components is given together.

Cr is an effective element for increasing the mechanical strength at ordinary and high temperatures as well as increasing the resistance to oxidation of an alloy when it is melted in the bare metal or combined with C to form a carbide. Nevertheless, when the quantity of contained Cr is too high, the thickness of the scale layer generated during general scale attachment to cause a scale having heat insulation and lubrication to attach to the surface of the core metal become thinner due to an increase in the oxidation resistance, and, of the damage described above which is caused to the core metal, galling due to seizure of the pipe material occurs frequently. Further, if the quantity of contained Cr is too low, the mechanical strength of the alloy at ordinary and high temperatures is decreased, and abrasion, wrinkles and cracks occur due to insufficient strength in the core metal.

Ni is a useful element for dissolving entirely in the bare metal without forming a carbide with C, and increasing the mechanical strength at ordinary and high temperatures due to solid solution hardening. However, the price of Ni is high compared to Cr, so increasing the mechanical strength of the alloy at ordinary and high temperatures with only Ni is costly, and a mechanical strength cannot be obtained that is as high as when coexisting with Cr. The adverse effects of the attachment scale layer becoming thinner due to scale attachment are far less with adding Ni than with adding Cr.

Accordingly, adequate mechanical strength at ordinary and high temperatures as well as a scale layer with an appropriate thickness was given to the core metal alloy, and in order to maintain economy for the alloy, the mechanical strength at ordinary and high temperatures was supplemented and the quantity of added Ni was reduced by making Ni which can increase the mechanical strength without thinning the scale layer the main component and adding thereto Cr within the tolerable limit.

From the aforementioned perspective, the upper limit of the quantity of contained Cr was set to 3% so as to not thin the thickness of the scale layer, and the lower limit was set to 1% to supplement the

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<sup>2</sup> [Translator's note: "comparative rhythm" is a typographical error for "proportion" in the Japanese source.]

mechanical strength. The quantity of contained Ni was fixed at three times the quantity of Cr, or in other words, the value of the ratio of Ni/Cr was 1 to 3, in order to increase the mechanical strength.

The basis for fixing the Ni/Cr ratio value of 1 to 3 is next described using the set of curved line drawings Fig. 1 and Fig. 2 and the set of drawings Fig. 3 and Fig. 4. Fig. 1 is a curved line drawing indicating the effects of the Ni/Cr ratio on the mechanical strength of an alloy at ordinary temperature when the quantity of contained Cr is 1.4%; Fig. 2 is a curved line drawing similarly with the effects at the same temperature of 900° C; Fig. 3 is a curved line diagram similarly with the effects at ordinary temperature when the quantity of contained Cr is 2.8%; and Fig. 4 is a curved line diagram similarly with the effects at the same temperature of 900° C.

As can be seen from these curved line diagrams, the pulling strength and elongation percentage at the ordinary temperature needed to prevent cracking, one of the damages causing lowering of the duration of core metal for piercing, is ill-suited for preventing cracks when the Ni/Cr ratio is less than 1 as the pulling strength is inadequate at 45 to 50 kg/mm<sup>2</sup>, and when the Ni/Cr ratio is more than 3 as the elongation percentage is lowered markedly. Also, it can be seen that the pulling strength at high temperatures necessary for preventing abrasion and wrinkles on the surface of the core metal, another type of damage, is inadequate at 5.2 or 5.3 kg/mm<sup>2</sup> when the Ni/Cr ratio is more than 3, and the elongation percentage is markedly decreased.

A determination was made from the above results to fix the selection of the value of the Ni/Cr ratio in a core metal alloy according to the present invention to a range of 1 to 3.

Mo and W are effective elements for increasing the mechanical strength of alloys particularly at high temperatures by being dissolved in an alloy base metal or being combined with C to form a carbide. On the other hand, increasing the quantity of contained Mo and W makes the scale layer generated so as to be attached to the surface of the core metal through scale attachment fragile. An example of the effects of adding Mo and W on the high temperature mechanical properties of a core metal alloy according to the present invention is shown in Fig. 5. This curved line drawing indicates the effect on the pulling strength and elongation percentage of the alloy caused by a change in the total quantity of Mo, W or both at a testing temperature of 900° C with a Ni/Cr ratio of 2.0 and a CR volume of 2.8%.

According to this curved line diagram, there is no effect of increasing the high temperature pulling strength until the total additive quantity of either one or two of Mo and W is 0.2%. However, with an additive quantity of 0.3% to 1.5%, the pulling strength gradually increases with the increase in the additive quantity, and with an additive quantity of 1.5 to 2.0%, the pulling strength increases rapidly with the increase in the additive quantity. At more than 2.0%, it can be seen that the pulling strength once again changes to a gradual increase.

With a core metal manufactured according to an alloy of the present invention, when piercing a solid round steel billet heated to approximately 1200° C, if the billet material being pierced is simply carbon steel, a core metal for piercing according to an alloy of the present invention having an additive quantity of less than 1.5% of a total of one or two of Mo and W adequately exceeds the durability of a conventional core metal. However, for a special steel such as when the material of the steel billet to be pierced is 13% chrome steel or 24% chrome steel, an additive quantity of a total of one or two of Mo and W of 1.5% to 3.0% is required.

Accordingly, the additive quantity of a total of one or two of Mo and W in an alloy according to the present invention was fixed at 0.3 to 3%.

Co is an element added to low alloy steels such as a core metal alloy according to the invention or a general carbon steel which is unique for lowering the hardenability of steel.

A core metal for piercing is pressed in a solid round billet heated to approximately 1200° C, so the surface temperature of the core metal for piercing immediately after piercing becomes approximately 1200° C to 1300° C, from the surface to approximately 5 mm inside becomes approximately 800° C, and the inside becomes less than 700° C.

A core metal heated to such a state is cooled to ordinary temperature with water immediately after piercing, and is then pressed again in a new billet; such heating and cooling is repeated in this manner. Through such repetitions, thin tortoise shell type cracks occur in the surface of the core metal, and this causes rolling marks to occur on the inside surface of the pierced pipe. Such tortoise shell type cracks originate in heat stress caused mainly due to the repeated heating and cooling.

In general, the heat stress of a steel body with a low hardenability and no quenching abnormalities causes compression stress at the surface of the steel body and pulling stress at the center of the steel body. In contrast to this, the heat stress of a steel body with a high hardenability and with quenching abnormalities causes pulling stress in the surface and compression stress at the center. In other words, the distribution of the heat stress switches. In general, repeatedly heating and cooling without compression stress becoming quenching abnormalities in the surface leads to less tortoise shell cracks.

The cross-section hardness of a round bar steel billet is measured after it is quenched in water, and the size of the hardenability can be expressed as the ratio  $d/r$  where  $d$  is the thickness of the hardened layer whose hardness is 40 or higher on the Rockwell C scale and  $r$  is the radius of the round bar. In other words, the smaller the  $d/r$  value, the lower the hardenability.

An example of the effect the quantity of the contained Co component has on the  $d/r$  value when a round bar with a radius of 25 mm according to an alloy of the present invention is quenched in water is shown in a curved line diagram of Fig. 6. From this curved line diagram, it can be seen that the lowering of the hardenability is remarkable until Co reaches 1.75%, and that the effects decrease when Co exceeds 1.75%.

Thus, the lower limit of the additive quantity of Co in an alloy of the present invention was set at 1% from the viewpoint of the effects of hardenability lowering, and the upper limit was set to 2% from a perspective that little hardening lowering effects are obtained for the economic increase in cost.

Cu is an effective element for being minutely separated in bare metal and increasing the pulling strength at ordinary temperatures. It is also an effective element for improving the adhesion to bare metal for the scale, enriched by the bare metal directly under the scale during attachment of a scale having heat insulation and lubrication as described above. If the additive quantity is below 1%, however, the improvement of the pulling strength at ordinary temperatures is low, and if the additive quantity is too high, the Cu enriched directly under the scale permeates into the crystal grain boundary of the bare metal at high temperatures, making the surface layer of the core metal fragile.

Thus, the lower limit of the additive quantity of Cu for an alloy of the present invention was set to 1%, and the upper limit was set to 2%.

With a preference over Cr, Ti and Zr are combined with C to form a carbide. Unlike a Cr carbide, a Ti and Zr carbide has a uniform distribution in the bare metal, and the solubility in bare metal at high temperatures is extremely low compared to a Cr carbide, so Ti and Zr are effective elements for lowering the partial melting point of the grain boundary and reducing the embrittlement of the grain boundary as well as increasing the pulling strength at high temperatures. Further, as a result of the decrease in the quantity of Cr carbide because precedence is made for Ti and Zr over Cr in forming the carbide, the Cr, W and Mo absorbed in the Cr carbide is decreased, the concentrations of these elements in the bare metal are accordingly increased, and the pulling strength of the alloy at high temperatures due to solid solution hardening improves. Nevertheless, if the additive quantity of Ti and Zr is too large, the liquid fluidity is markedly decreased when dissolving the alloy in air, and the castability when manufacturing the core metal is impaired.

Thus, the upper limit of the additive quantity of a total of either one or two types of Ti and Zr [illegible, r?] for an alloy of the present invention was fixed at 0.5% and the upper limit at 0.2%.

A core metal alloy for piercing a seamless pipe was described above; because a description for a core metal alloy for such expansion is exactly the same as that for a core metal alloy for piercing, it has been omitted.

Next, an embodiment is described.

The compositions of embodiments of core metal alloys for piercing according to the present invention are indicated in Table 1. The compositions of alloys according to the antecedent Patent Application Number S59-11899 [i.e., 1984-11899] invention as well as conventionally known types of alloys are also given alongside.

A number 10 ordinary temperature pulling test piece according to specification number JIS-Z-2201, a high temperature pulling test piece according to specification number JIS-G-0567, as well as piercing core metals for an Assel mill with diameters of 69 m/m, 72 m/m and 75 m/m were manufactured as raw materials for the alloys of the compositions indicated in Table 1. High temperature pulling tests were performed with a 5% strain rate every minute at a temperature of 900°C. Using these core metals, piercing tests of two types (C approximately 1% and Cr approximately 1.5%) of actual JIS SUJ bearing steel material (so-called high carbon chrome bearing steel material) were performed using the Assel mill. The results of these tests are indicated in Table 2. The durability of the core metal is indicated with the average number of piercing holes per core metal for piercing.

As seen in Table 2, the mechanical strength at ordinary and high temperatures of alloys according to the present invention is between 1.5 and 3 times that of conventionally known types of alloys, and it can be seen that it is equivalent or somewhat higher than that of the alloys in the Patent Application Number S59-11899 [i.e., 1984-11899] invention. The durability of a core metal manufactured with the alloy of the present invention is seen to be between 2 and 5 times that of a known alloy and from between 1.5 and 2 times that of the alloys of the Patent Application Number S59-11899 [i.e., 1984-11899] invention. The increase in the durability of the core metals according to alloys of the present invention is due to the effects of the tortoise shell cracks in the surface of the core metal decreasing due to the addition of Co to the alloy, the adhesion of a scale due to the addition of Cu, and the prevention of grain boundary separation of the carbide due to the addition of Ti and Zr.



Table 1. Alloy Composition Table (Weight Percent)  
[see original for figures]

|                    |   |     | C | Si | Mn | Cr | Ni | Mo | W | P | S | Co | Cu | Ti | Zr | Ni/Cr | Fe   |
|--------------------|---|-----|---|----|----|----|----|----|---|---|---|----|----|----|----|-------|------|
| Embodiment alloys  | No. a1  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       |      |
|                    | a2  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a3  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a4  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a5  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a6  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a7  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a8  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | a9  |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   |     |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
| Comparative alloys | Patent Application S59-11899 invention alloys | No. |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 1   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 2   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 3   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 4   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 5   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 6   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 7   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 8   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 9   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 10  |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    | Well-known alloys                             | 1   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 2   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |
|                    |   | 3   |   |    |    |    |    |    |   |   |   |    |    |    |    |       | Same |

[<sup>1</sup> Well-known alloys]

[<sup>2</sup> 3 Cr-1 Ni cast copper]

[<sup>3</sup> 1.5 Cr-0.75 Ni cast copper]

[<sup>4</sup> Remainder]

Table 2. Properties  
[see original for figures]

|                    |   |       | Mechanical properties at ordinary temperatures |                           | Mechanical properties at 900° C        |                           | Material for piercing tube | Durability (number of pierces per) |
|--------------------|---|-------|--|---------------------------|--|---------------------------|----------------------------|------------------------------------|
|                    |   |       | Pulling strength (kg/mm <sup>2</sup> )         | Elongation percentage (%) | Pulling strength (kg/mm <sup>2</sup> ) | Elongation percentage (%) |                            |                                    |
| Embodiment alloys  | No. a1  |       |  |                           |  |                           | Bearing copper             |                                    |
|                    | a2  |       |  |                           |  |                           | Same                       |                                    |
|                    | a3  |       |  |                           |  |                           | Same                       |                                    |
|                    | a4  |       |  |                           |  |                           | Same                       |                                    |
|                    | a5  |       |  |                           |  |                           | Same                       |                                    |
|                    | a6  |       |  |                           |  |                           | Same                       |                                    |
|                    | a7  |       |  |                           |  |                           | Same                       |                                    |
|                    | a8  |       |  |                           |  |                           | Same                       |                                    |
|                    | a9  |       |  |                           |  |                           | Same                       |                                    |
| Comparative alloys | Patent Application S59-11899 invention alloys | No. 1 |  |                           |  |                           | Same                       |                                    |
|                    |   | 2     |  |                           |  |                           | Same                       |                                    |
|                    |   | 3     |  |                           |  |                           | Same                       |                                    |
|                    |   | 4     |  |                           |  |                           | Same                       |                                    |
|                    |   | 5     |  |                           |  |                           | Same                       |                                    |
|                    |   | 6     |  |                           |  |                           | Same                       |                                    |
|                    |   | 7     |  |                           |  |                           | Same                       |                                    |
|                    |   | 8     |  |                           |  |                           | Same                       |                                    |
|                    |   | 9     |  |                           |  |                           | Same                       |                                    |
|                    | *1  | *2    |  |                           |  |                           | Same                       |                                    |
|                    |   | *3    |  |                           |  |                           | Same                       |                                    |
|                    |   |       |  |                           |  |                           | Same                       |                                    |

[<sup>1</sup> Well-known alloys]

[<sup>2</sup> 3 Cr-1 Ni cast copper]

[<sup>3</sup> 1.5 Cr-0.75 Ni cast copper]

#### 4. Brief Description of the Figures

Fig. 1 is a curved line diagram indicating effects of a Ni/Cr weight ratio on mechanical properties at ordinary temperatures when the quantity of Cr contained in an alloy of the present invention is 1.4%.

Fig. 2 is a curved line diagram indicating effects of a Ni/Cr weight ratio on mechanical properties at a temperature of 900°C when the quantity of Cr contained in an alloy of the present invention is 1.4%.

Fig. 3 is a curved line diagram indicating effects of a Ni/Cr weight ratio on mechanical properties at ordinary temperatures when the quantity of Cr contained in an alloy of the present invention is 2.8%.

Fig. 4 is a curved line diagram indicating effects of a Ni/Cr weight ratio on mechanical properties at a temperature of 900°C when the quantity of Cr contained in an alloy of the present invention is 2.8%.

Fig. 5 is a curved line diagram indicating effects of adding Mo and W on mechanical properties at a temperature of 900°C when the quantity of Cr contained in an alloy of the present invention is 2.8% and the Ni/Cr weight ratio is 2.0.

Fig. 6 is a curved line diagram indicating effects of adding Co on the hardenability of an alloy of the present invention.

Fig. 1

Pulling strength ( $\text{kg/mm}^2$ )

Elongation percentage (%)

[upper label] Pulling strength

[lower label] Elongation percentage

Fig. 2

Pulling strength ( $\text{kg/mm}^2$ )

Elongation percentage (%)

[upper label] Elongation percentage

[lower label] Pulling strength

Fig. 3

Pulling strength ( $\text{kg/mm}^2$ )

Elongation percentage (%)

[upper label] Pulling strength

[lower label] Elongation percentage

Fig. 4

Pulling strength ( $\text{kg/mm}^2$ )

Elongation percentage (%)

[upper label] Pulling strength

[lower label] Elongation percentage

Fig. 5

Pulling strength ( $\text{kg/mm}^2$ )

Elongation percentage (%)

[upper label] Pulling strength

[lower label] Elongation percentage

Fig. 6

Co additive quantity (%)

13 February 1985

## 1. Case identification

## 2. Title of the Invention

### 3. Party amending

**Shinhokoku Steel Co., Ltd.**

#### 4. Agent

Name (5847) Takehiko Suzue, Patent Attorney

[impression of a seal, mostly illegible] 2 [= Feb?] 1985

### Specification

(1) ~~Correct the entire specification of~~ the Scope of Claims as follows.

A. 9 lines from the bottom of page 4, correct "0.1 to 0.25% C" to "0.14 to 0.18% C".

C. Page 7 line 1, correct "0.1%" to "0.14%".

E. Same page line 3, insert “(refer to the embodiments given below)” after “piercing.”

F. Correct Table 1 and Table 2 on pages 19 and 20 as in the attached pages.

[see original for figures]

[illegible]

|  |   |   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |      |
|--|---|---|--|--|--|--|--|--|--|--|--|--|--|--|--|--|------|
|  |   | 7 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Same |
|  |   | 8 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Same |
|  |   | 9 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Same |
|  | 1 | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Same |
|  | 2 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Same |

[<sup>1</sup> Well-known alloys]

[<sup>2</sup> 3 Cr-1 Ni cast copper]

[<sup>3</sup> 1.5 Cr-0.75 Ni cast copper]

[<sup>4</sup> Remainder]

Table 2. Properties  
[see original for figures]

|                    |   |       | Mechanical properties at ordinary temperatures |                           | Mechanical properties at 900° C        |                           | Material for piercing tube | Durability (number of pierces per) |
|--------------------|---|-------|--|---------------------------|--|---------------------------|----------------------------|------------------------------------|
|                    |   |       | Pulling strength (kg/mm <sup>2</sup> )         | Elongation percentage (%) | Pulling strength (kg/mm <sup>2</sup> ) | Elongation percentage (%) |                            |                                    |
| Embodiment alloys  | No. a1  |       |  |                           |  |                           | Bearing copper             |                                    |
|                    | a2  |       |  |                           |  |                           | Same                       |                                    |
|                    | a3  |       |  |                           |  |                           | Same                       |                                    |
|                    | a4  |       |  |                           |  |                           | Same                       |                                    |
|                    | a5  |       |  |                           |  |                           | Same                       |                                    |
|                    | a6  |       |  |                           |  |                           | Same                       |                                    |
|                    | a7  |       |  |                           |  |                           | Same                       |                                    |
|                    | a8  |       |  |                           |  |                           | Same                       |                                    |
|                    | a9  |       |  |                           |  |                           | Same                       |                                    |
| Comparative alloys | Patent Application S59-11899 invention alloys | No. 1 |  |                           |  |                           | Same                       |                                    |
|                    |   | 2     |  |                           |  |                           | Same                       |                                    |
|                    |   | 3     |  |                           |  |                           | Same                       |                                    |
|                    |   | 4     |  |                           |  |                           | Same                       |                                    |
|                    |   | 5     |  |                           |  |                           | Same                       |                                    |
|                    |   | 6     |  |                           |  |                           | Same                       |                                    |
|                    |   | 7     |  |                           |  |                           | Same                       |                                    |
|                    |   | 8     |  |                           |  |                           | Same                       |                                    |
|                    |   | 9     |  |                           |  |                           | Same                       |                                    |
|                    | 1   | 2     |  |                           |  |                           | Same                       |                                    |
|                    |   | 3     |  |                           |  |                           | Same                       |                                    |

[<sup>1</sup> Well-known alloys]

[<sup>2</sup> 3 Cr-1 Ni cast copper]

[<sup>3</sup> 1.5 Cr-0.75 Ni cast copper]

## 2. Claims

1. A core metal alloy for piercing or expanding [insertion] a [end insertion] seamless steel pipe made from, by weight, 0.14 to 0.18% C, 1 to 3% Cr, 1 to 9% Ni, 0.3 to 3% of a total of one or two types of Mo and W, 1 to 2% of Co, 1 to 2% of Cu, 0.2 to 0.5% of a total of one or two types of Ti and Zr, and the balance Fe with inevitable trace quantities of impurities, and a weight ratio value for Ni/Cr of between 1 and 3.

2. A core metal alloy recited in Claim 1 characterized by the fact of further containing, by weight, according to need 1.5% or less of Si and/or 1.5% or less of Mn and as a deoxidizer.



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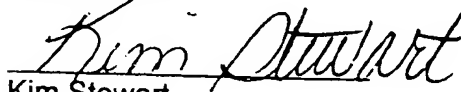
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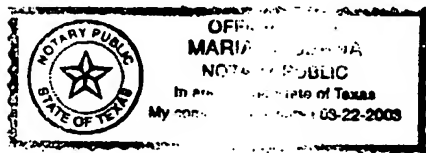
  
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